EXECUTIVE SUMMARY

Background

To meet the goals of AB 32 (the Global Warming Solutions Act of 2006) the Air Resources Board (ARB) identified and approved two early action measures to reduce direct emissions of high global warming potential (GWP) refrigerant from stationary refrigeration and air conditioning equipment that contribute to climate change. To inform development of these early action measures an inventory of direct greenhouse gas (GHG) emissions from stationary air conditioning and refrigeration equipment, and indirect GHG emissions created by power consumed during the operation of refrigeration equipment, was needed. ARB contracted with ARMINES to:

1) Estimate the refrigerant inventory and emissions of the stationary refrigeration and air conditioning sector in California; and
2) Estimate indirect greenhouse gas emissions from commercial and industrial refrigeration equipment, and evaluate current energy consumption and possible energy saving strategies achieved by integrating high-efficiency technical options in the commercial refrigeration sector.

Methods

The calculation method used for refrigerant inventory follows the Tier 2a method recommended by the Intergovernmental Panel on Climate Change (IPCC) guidelines in 2006, which is a "bottom-up" method based on the description of refrigeration equipment by sector. The sectors taken into account are: commercial refrigeration, industrial refrigeration, and air conditioning (including chillers). The installed base of equipment is described for each year and throughout the lifetime of the equipment, which can vary from 10 years to more than 40 years. In addition to annual emission estimates, the installed amount of refrigerant in equipment, or "banks" have been estimated to produce reliable projections of future refrigerant emissions through 2020.

ARMINES evaluated new refrigeration architectures and technologies that could result in a lower overall carbon footprint (total warming impact) from a combination of less refrigerant required in a system and potentially less energy required to operate the system.

For energy consumption of commercial refrigeration systems installed in California, the report describes in detail the commercial outlets where refrigeration systems are in use: Thirteen different categories of stores are defined, including supermarkets, grocery stores, restaurants, hotels, and gas stations. Commercial refrigeration systems are classified in three main categories depending on the size, the technology and their energy consumption: stand-alone equipment, condensing units, and supermarket centralized systems. In order to assess the energy consumption of each type, more than 100 detailed visits to stores were conducted in order to evaluate the types of equipment used in commercial refrigeration.

The annual energy consumption of all commercial refrigeration systems have been estimated by evaluating the energy use of the 28 different types of equipment used in these systems. The calculation method developed takes into account the equipment types, their operating conditions, and the outdoor temperatures of the eight climatic zones of California.

Three main technical options have been evaluated for energy saving in supermarkets:
1) Installing glass doors on medium-temperature display cases;

2) New technologies for auxiliary components (efficient lighting, efficient fan motors, better control of defrosting devices), and
3) Better control of the refrigeration system condensing pressure.

Energy savings from using these technical options have been estimated for a typical supermarket and for a typical small grocery store in California.

Results

Annual GHG emissions in 2004 from stationary refrigerant sources in California were estimated at 16 million metric tons of carbon dioxide equivalents ($MMTCO_2E$). Air-conditioning is the dominant source of these emissions, accounting for 55 percent of the total, with the remaining from commercial refrigeration (19 percent), chillers (19 percent), and industrial refrigeration (7 percent).

An additional 185 $MMTCO_2E$ of potential emissions exists in the installed base, or "bank" of refrigerant in equipment. The majority of the bank, 57 percent, is represented by HCFC-22, and another 40 percent is comprised of hydrofluorocarbons (HFCs). The production of HCFC-22 will be phased out beginning in 2010, and its replacement with higher-global warming HFCs could double the global warming impact from this sector if emission rates remain the same (HCFC-22 has a GWP of 1,500; and a likely replacement is R-404A, with a much higher GWP of 3,260).

Equipment changes in commercial refrigeration lead to a potential three-fold reduction in the carbon footprint of grocery stores, supermarkets, and food-related businesses by replacing current centralized systems (which tend to be very emissive) with more leak-tight indirect systems. In indirect systems, the high-GWP refrigerant is contained in a much smaller circuit in the machinery room and a heat transfer fluid with a negligible GWP provides the coldness in the display cases located in the sales area.

Annual energy consumption of commercial refrigeration systems in California is significant, accounting for up to 8 percent of all electrical usage in the state, with year 2004 consumption estimated at 20,200 GWh (giga-watt hours; or billion-watt hours) for all Californian commercial refrigeration. Grocery supermarkets used 5,300 GWh, or 25 percent of the total commercial refrigeration energy usage. Current energy consumption can be decreased 30 percent for supermarkets, and decreased 20 percent for the entire commercial sector, by using currently available best technologies for stand-alone equipment, condensing units, and supermarket centralized systems. The payback period from applying best technologies vary from three months to less than four years.

Conclusions

This study establishes that refrigerant GHG emissions from stationary refrigerant sources in California are significant, and will most likely increase through 2020 without changes made to the types of equipment technologies used. Progress has been made by some commercial chains, and refrigerant emissions have been lowered from an average of about 30% per year to about 15%, but this progress needs to be consolidated and furthered.

Indirect systems using CO_2 as heat transfer fluid is a technical option decreasing the refrigerant charge required four to eight-fold, and radically changes future refrigerant emissions with very significant GHG reductions. In parallel with possible refrigeration system evolution, several technical options are available to limit the energy consumption of commercial refrigeration systems. Significant energy gains are realized from the redesign of display cases by adding

transparent doors for all operating temperatures, the use of LED lighting, and the adoption of efficient technologies for fan motors and defrosting.